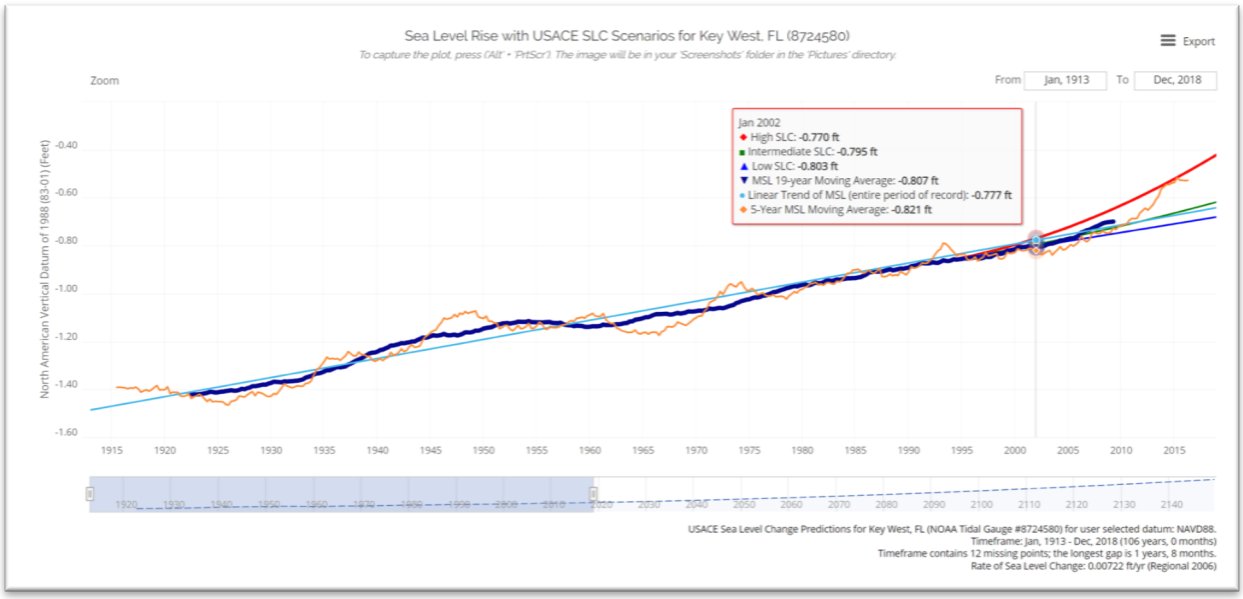
US Army Corps of Engineers
Sea Level Tracker User Guide



User Guide
Version 1.0
December 2018

U.S. Army Corps of Engineers, Washington, DC
Climate Preparedness and Resilience Community of Practice

Abstract:
Sea level change has been a persistent trend for decades in the United States and elsewhere in the world. Observed and reasonably foreseeable global sea level rise means that local sea levels will continue beyond the end of this century. In most locations, global sea level rise results in local relative sea level rise. For these locations, the change already have caused impacts such as flooding and coastal shoreline erosion to the Nation's assets already located at or near the ocean, which will continue to change in severity. In other locations, (e.g., Pacific Northwest and Alaska), vertical land movement means that local relative sea level is falling. While this may seem to be a benefit, impacts to shoreline erosion and stability in these locations can be just as severe as elsewhere. Along the U.S. Atlantic Coast alone, almost 60 percent of the land that is within a meter of sea level is planned for further development. Wise decision-making requires adequate information on the potential rates and amount of sea level change. Accordingly, the risks posed by sea level change motivate decision-makers to ask: “What is current rate of sea level change, and how will that impact the future conditions that affect the performance and reliability of my infrastructure, or the current and future residential, commercial, and industrial development?” To better empower data-driven and risk-informed decision-making, the U.S. Army Corps of Engineers (USACE) has developed the Sea Level Tracker. The Sea Level Tracker is a user-friendly graphical platform that provides a consistent and repeatable method to visualize the dynamic nature and variability of coastal water levels at tide gauges, allows comparison to USACE projected sea level change scenarios, and supports simple exploration of how sea level change has or will intersect with local elevation thresholds related to infrastructure (e.g., roads, power generating facilities, dunes),and buildings. Taken together, decision-makers can align various sea level rise scenarios with existing and planned engineering efforts, estimating when and how the sea level may impact critical infrastructure and planned development activities.

Preferred Citation:
Sant-Miller, A., Huber, M., and White, K.D. (2018). US Army Corps of Engineers Sea Level Tracker User Guide. US Army Corps of Engineers: Washington, DC.

Introduction

Sea level rise has been a persistent trend globally for decades (Parris et al., 2012, Hall et al. 2016, Sweet et al., 2017). This rise is expected to continue beyond the end of this century, which will cause significant impacts to the Nation's assets already located at or near the ocean (e.g., Sweet et al., 2014, Sweet and Marra, 2016). In most locations, global sea level rise results in local relative sea level rise. For these locations, the change already have caused impacts such as flooding and coastal shoreline erosion to the Nation's assets already located at or near the ocean, which will continue to change in severity. For example, along the U.S. Atlantic Coast alone, almost 60 percent of the land that is within a meter of sea level is planned for further development, with inadequate information on the potential rates and amount of local relative sea level rise. This poses significant risk over the lifetime of the affected coastal areas. In other locations, (e.g., Pacific Northwest and Alaska), vertical land movement means that local relative sea level is falling. While this may seem to be a benefit, the associated impacts to shoreline erosion and stability in these locations can be just as severe as elsewhere.

Given its mission areas of navigation and flood and coastal risk management, the United States Army Corps of Engineers (USACE) has been aware of the impacts of changing sea levels to shoreline erosion and stability and flooding (e.g., USACE 1979). UASCE has released formal guidance (e.g., USACE 1989, USACE 2013a, USACE 2013b, USACE, 2014) to incorporate changing sea levels in project planning and design. Now, all current and future coastal projects must account for the impacts of changes in local mean sea level (LMSL) throughout a project life-cycle. To better enable the required analysis and to empower deeper exploration of sea level rise more broadly, USACE has developed of a suite of tools and web applications for repeatable, quantitative analysis of LMSL.

Within that suite, the Sea Level Tracker was developed in response to the need to easily visualize observed changes in sea level and to compare trends to projected changes per USACE Engineer Regulation 1100-2-8162 and Engineer Technical Letter (ETL) 1100-2-1. The tool shows the historical, observed changes in mean sea level (MSL) as measured sand reported for National Oceanic Atmospheric Administration (NOAA) tide gauges, mapped against the USACE sea level change (SLC) projections. Taken together, the tool enables the comparison of actual SLC with USACE SLC projections (as described in ER 1100-2-8162), along with observed monthly water levels and the computation of SLC trends based on historical data. Additionally, the tool allows for the mapping of these trends and projections against existing elevation thresholds, which may represent critical infrastructure elevation levels or other elevations of interest to the user. Finally, the tool enables users to visualize the indirect impacts of changing sea level on extreme water levels (EWLs) as calculated by NOAA. Working together, these components can help decision-makers can align various sea level rise scenarios with existing and planned engineering efforts, estimating when and how the sea level may impact critical infrastructure and planned development activities.

The purpose of this manual is to inform the users of Version 1.0 of the Sea Level Tracker, released in November of 2018. The document includes the following: (1) a discussion of the technical concepts incorporated into the tool, and (2) guidance for user interaction. This user guide does not cover all possible situations that one may encounter while using the tool, and Sea Level Tracker is not a substitute for professional engineering judgment.

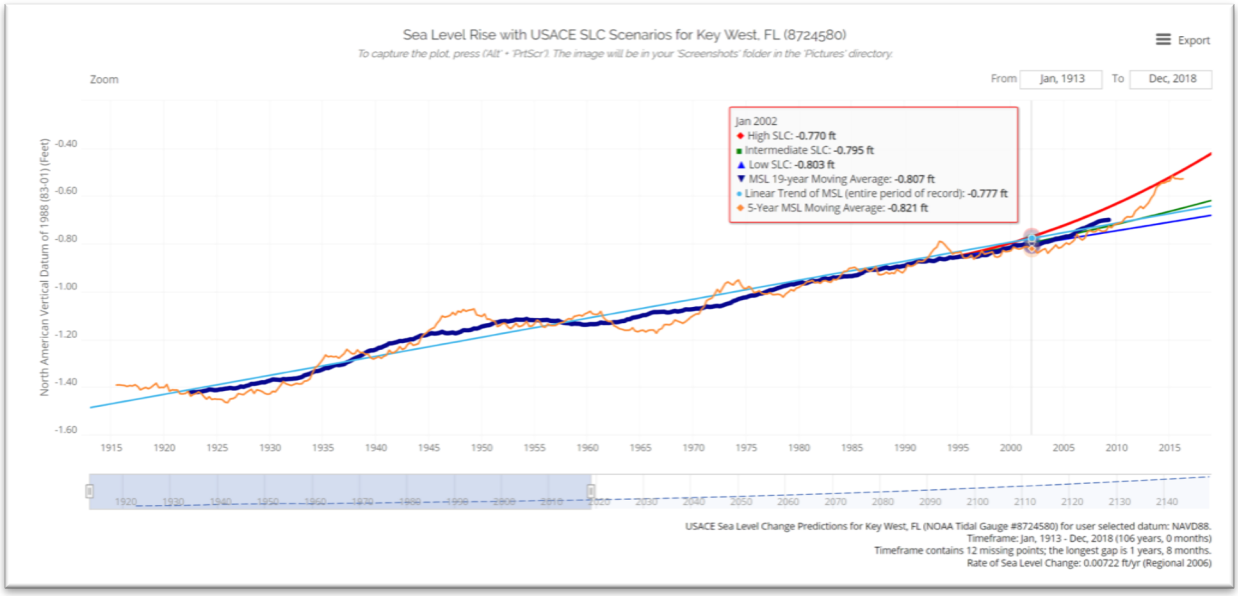


Figure 1: *The Sea Level Tracker analyzing Key West, FL (8724580) using the NAVD88 datum*

Accessing the Tool

The Sea Level Tracker is available at: http://climate.sec.usace.army.mil/slr_app/

1 Technical Background

As a comprehensive platform, the Sea Level Tracker blends authoritative tide gauge data from NOAA, technical content from statistics, geological science, hydrology, software development, and engineering into one analytical tool. The following sub-sections aim to provide a foundational understanding of the tool, its inputs, and the analysis it enables. The content included in this document should be treated as context required to use the application, not comprehensive technical documentation. Users and readers are encouraged to explore the references included at the end of the document to develop a deeper understanding of the science and engineering theory behind the Sea Level Tracker. Additionally, further reading is recommended for users intending to use analytic outputs for future planning or in engineering decision-making.

1.1 General Capabilities of the Sea Level Tracker

This Technical Background section highlights 1) general tool capabilities, 2) various data elements that a user can pass as parameters to the visualizations and data tables, and 3) scientific and engineering background that supports the USACE sea level change scenario projections. As a deployed application, the Sea Level Tracker enables the comparison of actual SLC with USACE SLC projections (as described in ER 1100-2-8162), while quantifying and visualizing observed water levels and SLC trends based on this historical data. To enable higher-order analysis, the tool can map these trends and projections against existing threshold elevations for critical infrastructure and other local elevations of interest. The tool also provides easy access to EWLs calculated by NOAA. All of these components, working together, can help decision-makers can align various sea level rise scenarios with existing and planned engineering efforts, estimating when and how the sea level may impact critical infrastructure and planned development activities.

In practice, the Sea Level Tracker aims to foundationally address two defined needs:

1. Show actual MSL vs. the projected SLC scenarios plainly
2. Visually represent the observed rate of sea level change at a user-selected location

To offer data-driven insights, the tool relies on an interactive user interface with four main sections:

1. ***Data Entry Interface:*** Within five unique data entry panes, the user can configure the elements he or she wishes to visualize and explore within the application. On the first pane, the user selects the location, gauge, and vertical reference datum to be analyzed, as well as the SLC rate that is a foundation for the calculated SLC scenarios. On the subsequent panes, the user configures characteristics of the primary visualization and its underlying data, including moving averages of historical data, trend lines, extreme water levels, and critical elevations for comparison.
2. ***Location Map:*** For a more visual experience, the user can select a location and gauge on the map for analysis. This tab helps the user maintain geographic context during the analysis and allows the user to explore nearby locations and gauges with ease.
3. ***Visualization Tab:*** Built to house an easy-to-interpret data visualization, this tab is the primary means of interacting with the user-configured analysis. The generated plot captures the historic hydrologic behavior at the selected location and gauge (based on the selected datum), while presenting historic trends and averages of interest to the user. The final output is configured by the user's selections in the *Data Entry Interface*, and the resulting visualization can be captured as a screenshot or downloaded as an image file (for distribution with embedded metadata).
4. ***Data Table(s) Tab***: For deeper inspection, the Sea Level Tracker simultaneously presents the raw data used to populate the visualization tab. Here, all embedded data is at the user's fingertips, where he or she can select variables of interest and filter the selected variables to desired analytical ranges. This table can be downloaded and saved as a CSV file for distribution.

1.2 Data Used in Sea Level Tracker

As an analytics platform, the Sea Level Tracker does not generate its own data. Rather, the application automatically pulls authoritative tide gauge data from the NOAA Center for Operational Oceanographic Products and Services (CO-OPS) Application Programming Interface (API), runs a series of calculations, and returns the described outputs. The CO-OPS API is a flexible retrieval mechanism for direct access to CO-OPS' products, which include as historic water levels, predictions, currents, and meteorological observations. The Sea Level Tracker processes the user's selected inputs and sends a request to the API, which returns raw water level data for the user-selected tidal gauge. Therefore, the initial rendering of the selected inputs can take some time, depending on connection speed. For more information, documentation on querying data through the CO-OPS API can be found here, where the types of information accessible via the API are listed in detail under Resource Types.

As mentioned above, the user can configure the visualization's parameters in the data entry interface. This interface is composed of five panes, each with a unique focus. After configuring the first pane, the user can press the "Visualize Selection" button, which causes the application to process the configured inputs and render the most simplistic visualization of the selected location. The Sea Level Tracker will not run unless the first pane is configured, as the elements within this pane configure the CO-OPS API request (though the user can run the tool at any point after configuring the first pane).

1.2.1 Pane #1: *Gauge, datum, and rate*

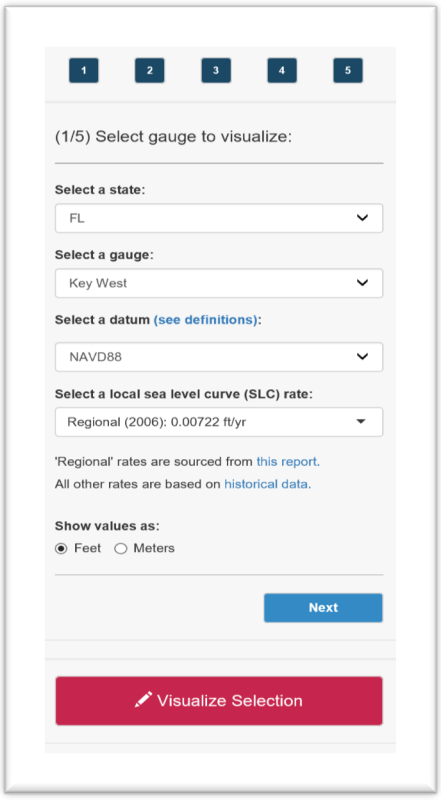


Figure 2: *Data Entry Pane #1*

The first pane allows the user to configure the five primary parameters of the Sea Level Tracker. Four of the five parameters are passed directly to the CO-OPS API and, accordingly, will directly impact the raw data (state, gauge, datum, and unit selection). The location elements are converted to a gauge identification number, which is correlated with historic data provided by NOAA and presented with the tool's outputs. For ad hoc analysis, a user can use the selected identification number to directly query the API on their own.

The datum value and unit parameters are passed to the CO-OPS API as well, as the tool does not calculate these transformations itself. Rather, the Sea Level Tracker defers to NOAA as the definitive source, extracting preprocessed data to match the user's selection. For some gauges, not all datum options are offered by NOAA, and, accordingly, these choices are removed from the drop down.

Finally, the user can select a SLC rate on the first pane. These values are extracted from NOAA as well, but not directly from the API. They can be accessed here, while the regional rates are sourced from Technical Report NOS CO-OPS 065, "Estimating Vertical Land Motion from Long-Term Tide Gauge Records". These rates are used to calculate the SLC scenarios in the tool.

1.2.2 Pane #2: *Moving average water surface scenarios and monthly means*

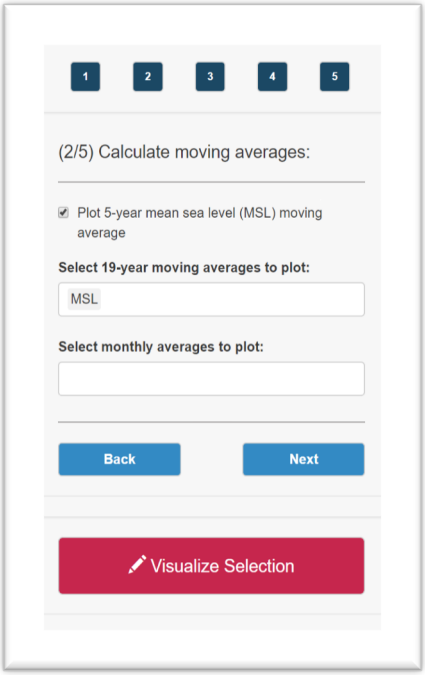


Figure 3: *Data Entry Pane #2*

The second pane allows the user to select which measures of historical data he or she wishes to present as smoothed, moving averages. As a default, the 19-year midpoint MSL moving average is selected. This time period is tied to the metonic cycle. The midpoint moving average is selected to balance the moving average. The user also has the option of adding the 5-year midpoint MSL moving average, as well as the raw the monthly mean values for any of the tidal phases. The monthly values are pulled directly from the API when the Sea Level Tracker requests the data using the "monthly mean" parameter documented here. These values are the basis for all the moving averages calculated in the tool.

Moving averages are calculated based on the defined time period window, centered at each plotted point. For this reason, the scenarios are cropped when there are no values to base this calculation from on either end of the window. This is particularly apparent when there are gaps in the data collected from the CO-OPS API. Note, gauges with missing values will require a brief "burn-in" period as the moving averages are smoothed over time. This can be seen as irregularities or sudden increases or decreases in the data.

1.2.3 Pane #3: *Linear trend lines*

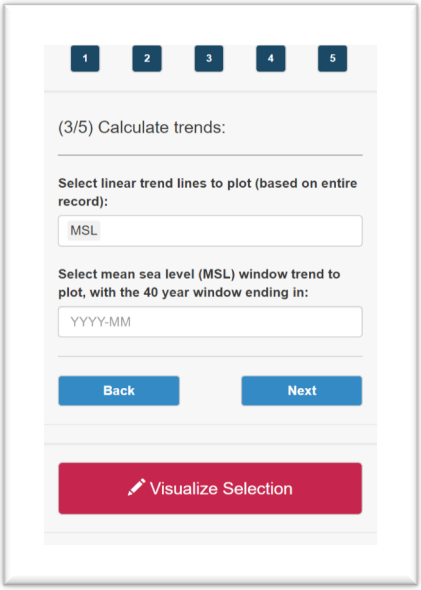


Figure 4: *Data Entry Pane #3*

The third pane allows the user to select trend lines to plot and visualize in the tool. Trends are calculated using a best-fit linear model, where both the y-intercept of the line and the linear coefficient are pulled from the model parameters. For the primary linear trend lines, these models are optimized to fit the entire period of record for the gauge. If the user wishes to reduce the period used when calculating these values, the user can define a 40-year window, where the entered date is the final month in that measured window. For these shorter, 40-year periods of record, all calculated trends are based on just MSL.

As specified in ER 1110-2-8162, 40 years of record are recommended to develop sea level trends and, accordingly, the user cannot select a window less than 40 years. If the period of record is shorter than 40 years, a warning will appear here on pane three.

1.2.4 Pane #4: *Extreme water levels (EWLs)*

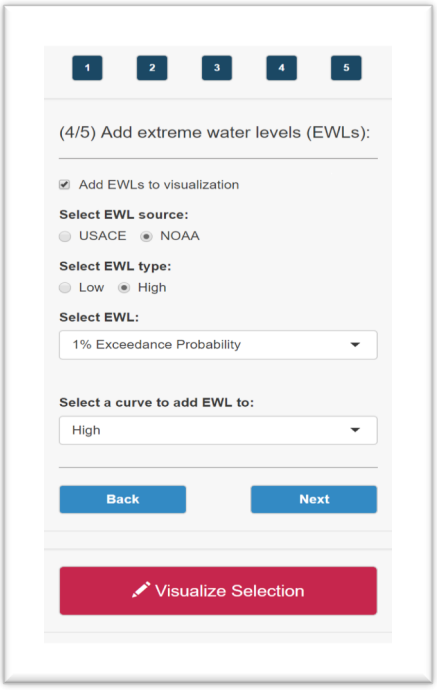


Figure 5: *Data Entry Pane #4*

The fourth pane allows the user to add extreme water levels (EWLs) to the resulting visualizations. The EWLs are statistically-derived water levels based on the probability of an extreme hydrologic event or storm as calculated by NOAA. These probabilities can be interpreted as approximately the inverse of the rarity of an event, where a 1% exceedance probability correlates with the most extreme storm in the last 100 years, the 2% exceedance probability correlates with the most extreme storm in the last 50 years, and the 100% exceedance probability correlates with the most extreme storm in the last year, etc. The user can select which SLC scenario to apply the EWL value to, allowing for even greater understanding of these indirect impacts of SLC..

There are two methods for calculating the selected exceedance probability: the generalized extreme value (GEV) probability distribution function, which is used by NOAA, and the percentile function, which is used by the US Army Corps of Engineers. Both measures are statistically valid, but they are based on different analytic approaches and produce different results. For more information, EWLs and their associated implications are detailed in this technical report.

1.2.5 Pane #5: *Critical elevations for comparison*

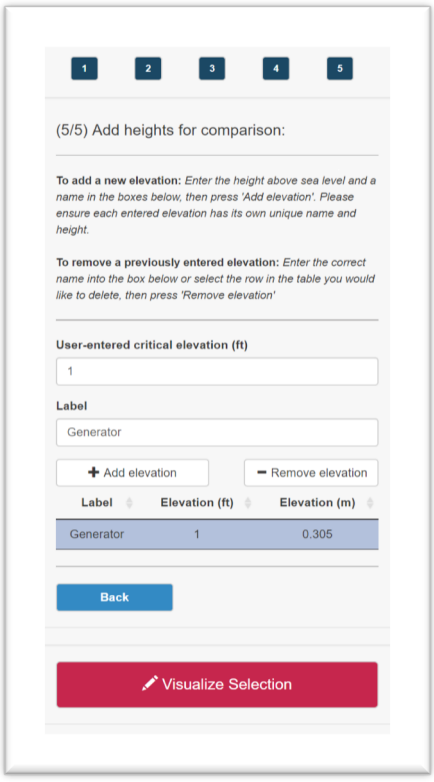


Figure 6: *Data Entry Pane #5*

The fifth pane allows the user to add critical elevations, or user-defined heights above sea level, for comparison with the visualized outputs. These elevations can be used as a benchmark for both the measured historical water levels and for the SLC scenarios and extreme water levels that are projected into future years.

The tool allows the user to enter a value and define a name for the defined elevation (as it will appear in the tool for the user's records). The tool will also transform the entered elevation between metric and English units, allowing for consistency if the user chooses to change the units selected on the first pane.

This pane allows for customization of the final analysis, helping decision-makers can align various sea level rise scenarios with existing and planned engineering efforts. While the Sea Level tracker is not a prediction engine, adding defined elevations can help provide insight into how sea level may impact critical infrastructure and planned development activities under various risk scenarios (i.e., a one-in-100-year storm occurring under a moderate SLC scenario twenty years into the future). For more information, the implications of sea level change and sea level rise are discussed in this technical letter.

1.3 Sea Level Change Scenarios

At any location, changes in local relative sea level (LRSL) reflect the integrated effects of global mean sea level (GMSL) change, plus local or regional changes of geologic, oceanographic, or atmospheric origin. Therefore, when projecting various sea level change scenarios at the local level, analytical tools must consider both global and local sea level change effects. The Sea Level Tracker does just this, where all three sea level change scenarios (low, intermediate, and high) include the local (or user selected) sea level change rate, resulting in different acceleration scenarios for global sea level changes.

All three scenarios originate from 1992 in the Sea Level Tracker. Currently, this is the most robust starting point for the SLC scenarios, as 1992 is the center year, or midpoint, of the NOAA National Tidal Datum Epoch (NTDE) of 1983– 2001. It is this epoch that is used to define the various tidal datums (Mean High Water, for instance, and local MSL) and it is expected that the average of the 19 years of hourly readings from each tide gauge will be zero on or about June 30, 1992. This attempts to index the projections to the actual average water surface of the current NTDE (83-01).

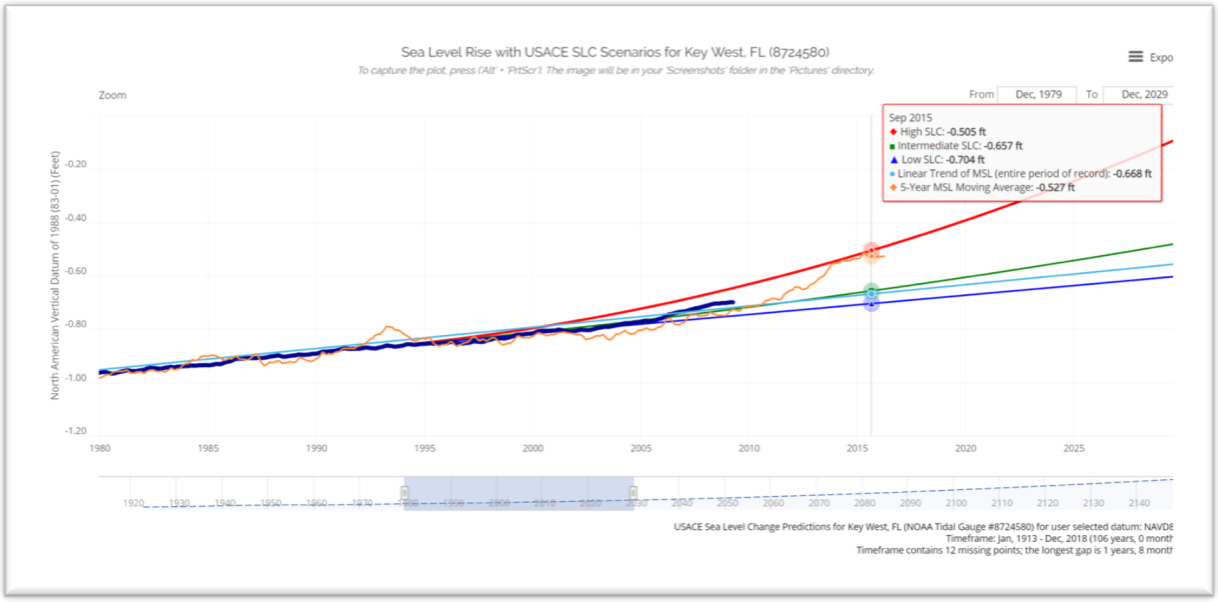


Figure 7: *Sea level change scenarios for Key West, FL (8724580), using a regional rate (2006) of 0.00722 ft/yr*

All three sea level scenarios rely on the following formula (USACE 2013):

$$y = \alpha t + \beta t^2 \quad (1)$$

In (1) above,

- α is the local sea level rate, which is configured by the user in the Sea Level Tracker.
- *t* is a measure of time, calculated as the difference between 1992 and the date at which the user is generating an estimate.
- *β* is the coefficient used for different acceleration scenarios global sea level rise.

As shown in above, variation in the sea level scenarios result from changes in *β*. For the low rise scenario, acceleration of global sea level rise is assumed to be zero. As a result, (1) simplifies to (2) below, which is the linear relationship between the selected local sea level rate and time. Adjusting this parameter (the local SLC rate) can result in significant variation in all three scenarios.

$$y = \alpha t \quad (2)$$

In the intermediate and high sea level rise scenarios, β is a positive, non-zero value that results in quadratic acceleration of the scenarios. This value is equal to 2.71E-5 for the intermediate scenario and 1.13E-4 for high scenario. Due to the increased polynomial factor on time in this component of (1) above, all three scenarios result in reasonably similar estimates in the near future, but significantly different scenarios further into the future.

2 Interacting with the Sea Level Tracker

The Sea Level Tracker is designed to be both analytically robust and intuitive in use. It is composed of multiple interfaces, each with a unique utilitarian value. This section of the User Guide aims to direct the user through the application and address any potential questions the user may have on interaction with the tool. Future iterations of the guide will address any ad-hoc questions and concerns that are not addressed in Version 1.0.

The tool has two primary pages, which are toggled by user selections on the header bar. The welcome page, or landing page, is designed to offer the user general background information. The level of detail is not meant to fully explain the application or fully support its use; that is the goal of the user guide. Rather, the landing page aims to direct the user to critical, supplemental resources and this guide, while providing generic, introductory language for a new user.

The second option in the header bar brings the user to the page used to run the application, explore analytic outputs, and deliver data-driven insights. The remainder of this section is dedicated to walking through this component of the tool.

2.1 Data Entry Panel

On the left-hand side of the application page is the Data Entry panel, composed of five unique panes. The user can move between the panes by selected the "Next" and "Back" bottoms at the bottom of the panel (located above the "Visualize Selection" button). Alternatively, the user can jump between panes using the radio buttons at the top of the panel, which include the pane number and hover-over-titles to improve ease of use. It is recommended that the user explore all five panes, even if the user does not wish to enter parameters on each (note, for more information on the motivation behind the five panes, see Section 1.2 of this User Guide).

At the bottom of the data entry panel at large is the submit button, labeled "Visualize Selection." This button is present, regardless of which pane is currently selected, and no analytic outputs will be calculated before the user presses this button. When pressed, the Sea Level Tracker will take some time to process the data, but it should take no longer than 15 seconds depending on network speed. If the application is taking longer than 15 seconds to process the inputs, and the "pending" icon no longer appears over the other panels, it is recommended that the user re-press the "Visualize Selection" button, as a logging issue may have occurred.

As alluded to, each unique pane has its own differentiated value, and, therefore, the user must interact with each differently. See below.

2.1.1 Pane #1: *Tide gauge, datum, and rate*

The first pane allows the user to configure five critical elements of the Sea Level Tracker. Unless these elements are selected and entered by the user, the application will not run.

1. ***State:*** In this dropdown, the user must select the state of the desired gauge to visualize. The states are alphabetically organized and the subsequent gauge options in the dropdown are dependent on the state selected, i.e. changing the state changes to possible gauges the user can select.
2. ***Gauge:*** In this dropdown, the user must select the desired gauge to visualize in the Sea Level Tracker. As mentioned above, the user's options are dependent on the selected state, where the only gauges present in the dropdown are those present within the state selected above.
3. ***Datum:*** This dropdown only appears after the user selects a location, i.e. both a state and a gauge. Note, the tool's datum options are dependent on the gauge selected, as NOAA does not measure all possible datum values for all gauges available in the Sea Level Tracker. By default,

the selected value is the NAVD88 datum, and if it is not available, the MSL datum. A few locations (e.g., Puerto Rico) have established local datums other than NAVD88. For more information and an explanation of each datum, the user is encouraged to click the hyperlink associated with the drop down in the UI or follow this link.

4. ***Sea Level Scenario Rate:*** This dropdown only appears after the user selects a location, i.e., both a state and a gauge. Note, the rate options are dependent on the gauge selected, as the tool defers to NOAA on local sea level rates measured at the location in question. By default, the Sea Level Tracker uses the 'Regional' rates sourced from this report. All other rates are based on historical data. The user can also enter their own rate by selecting the "Enter custom rate" value in the dropdown, though it is recommended that the user use the predefined values.
5. ***Units:*** On the first pane, the user can toggle different unit measurements for the tool. Changes to this parameter will impact all analytic outputs in the Sea Level Tracker, as the user-selected value is passed to the NOAA API, adjusting all the foundational data in the application. For the Sea Level Tracker, the default value is "Feet."

2.1.2 Pane #2: *Moving average scenarios and monthly means*

The second pane allows the user to select which measures of historical data he or she wishes to present as moving averages. By default, the 19-year midpoint MSL moving average is selected. On this pane, the user also has the option of adding a 5-year midpoint MSL moving average or the raw monthly averages.

1. ***5-year MSL moving average***: This moving average can be toggled on or off using the checkbox selection at the top of the pane. Currently, the only 5-year moving average the user can add to the tool is based on mean sea level. As a default, this scenario is not calculated or presented as an output.
2. ***19-moving averages:*** The user can select 19-year moving averages for a particular tidal datum phase by manually typing them into the bar or by entering the cursor into the bar and selecting the desired value from the dropdown. Values can be removed by selecting them in the bar and pressing "Backspace" or "Delete." The user can choose any combination of the following options: *Highest, MHHW, MHW, MSL, MLW, MLLW, or Lowest.* These options are explained by clicking the "Term Definitions" button in the top right of the application. As a default, the 19-year MSL moving average is selected.
3. ***Monthly Averages:*** The user can select monthly averages by manually typing them into the bar or by entering the cursor into the bar and selecting the desired value from the drop down. Values can be removed by selecting them in the bar and pressing "Backspace" or "Delete." The user can choose any combination of the following options: *Highest, MHHW, MHW, MSL, MLW, MLLW, or Lowest.* These options are explained by clicking the "Term Definitions" button in the top right of the application. As a default, none of these values are calculated.

2.1.3 Pane #3: *Linear Trend Lines*

The third pane allows the user to select trend lines to plot and visualize in the tool. The user can either fit a linear trend line to the entire period of record or within a defined 40-year period of record.

1. ***Entire Period of Record:*** The user can select linear trend lines by manually entering the desired measure into the bar or by entering the cursor into the bar and selecting the desired value from the drop down. Values can be removed by selecting them in the bar and pressing "Backspace" or "Delete." The user can choose any combination of the following options: *Highest, MHHW, MHW, MSL, MLW, MLLW, or Lowest.* These options are explained by clicking the "Term Definitions" button in the top right of the application. As a default, none of these values are calculated.
2. ***40-year Period of Record:*** The user can select any date within the gauge's period of record as the end date for the 40-year window. The start date of this window is 40 years prior to the entered date, on the month. The user should enter this value in the YYYY-MM format. All 40-year linear trends use the MSL value. Future releases of the Sea Level Tracker will allow the

user to create 40-year linear trends for alternate measures. By default, no 40-year linear trend is calculated.

2.1.4 Pane #4: *Extreme water levels (EWLs)*

The fourth pane allows the user to add extreme water levels (EWLs) as calculated by NOAA to the analytic outputs. If the user chooses to add EWLs and accordingly checks the box on this pane, the user can configure various parameters of the EWLs.

1. ***EWL Source:*** By default, the NOAA method is selected for extreme water levels. Using the radio buttons, the user can select the USACE calculation method. For a deeper explanation of these two methods, please review Section 1.2.4 and read the supporting documents included in the reference section below.
2. ***EWL Type:*** Using the radio buttons, the user can select either low or high extreme water level. The high EWL adds the calculated value to the scenario, while the low EWL subtracts the calculated value from the scenario. By default, the high option is selected, adding the extreme water value to the selected scenario.
3. ***EWL Exceedance Probability:*** Using the dropdown, the user can select the desired exceedance probability for the extreme water levels measure. Changing this value adjusts the magnitude of the extreme water value, dependent on the methodology selected in the above radio button. For a deeper explanation of the interpretation of exceedance probability, please review Section 1.2.4 and read the supporting documents included in the reference section below. Be default, the "1% Exceedance Probability" is selected.
4. ***Scenario Selection:*** Using the dropdown, the user can select a scenario to add the EWL value to or subtract the EWL value from. The user can chose to any of the three primary scenarios discussed above. By default, the "High" scenario is selected.

2.1.4 Pane #5: *Critical elevations for comparison*

The fifth pane allows the user to add critical elevations, or user-defined heights above a defined datum, for comparison with other calculated values. To add values, the user must define the characteristics of the critical elevation in the text entry bars on the pane. Unless the user formally enters both a critical elevation and a name for the critical elevation, the value will not be added. All entered values will appear in the table below on this pane.

1. ***To add a new elevation:*** Enter the height above sea level and a name in the boxes, then press 'Add elevation'. Please ensure each entered elevation has its own unique name and height.
2. ***To remove a previously entered elevation****:* Enter the correct name into the box or select the row in the table you would like to delete, then press 'Remove elevation.' Selecting the value in the table will automatically populate the name and elevation box for the removal.

2.2 Map Panel

To the right of the data entry panel are three unique panel options. By default, when the user navigates to the application page, the Sea Level Tracker presents the map panel. This panel is used for visual interpretation of the selected location, while also simultaneously functioning as an alternative option to select a gauge for analysis.

If using the map to select a location, the user must first click the map to select a state. When successfully clicked, the data entry panel will be updated with the user selected state. Next, the user must click the desired gauge location on the map. Once a state is selected on the map, the user can select different gauges within that state on the map.

The mapping panel uses the Leaflet and ESRI libraries to visualize global locations. The mapping software is regularly updated and should be representative of current street, landscape, and water

characteristics.

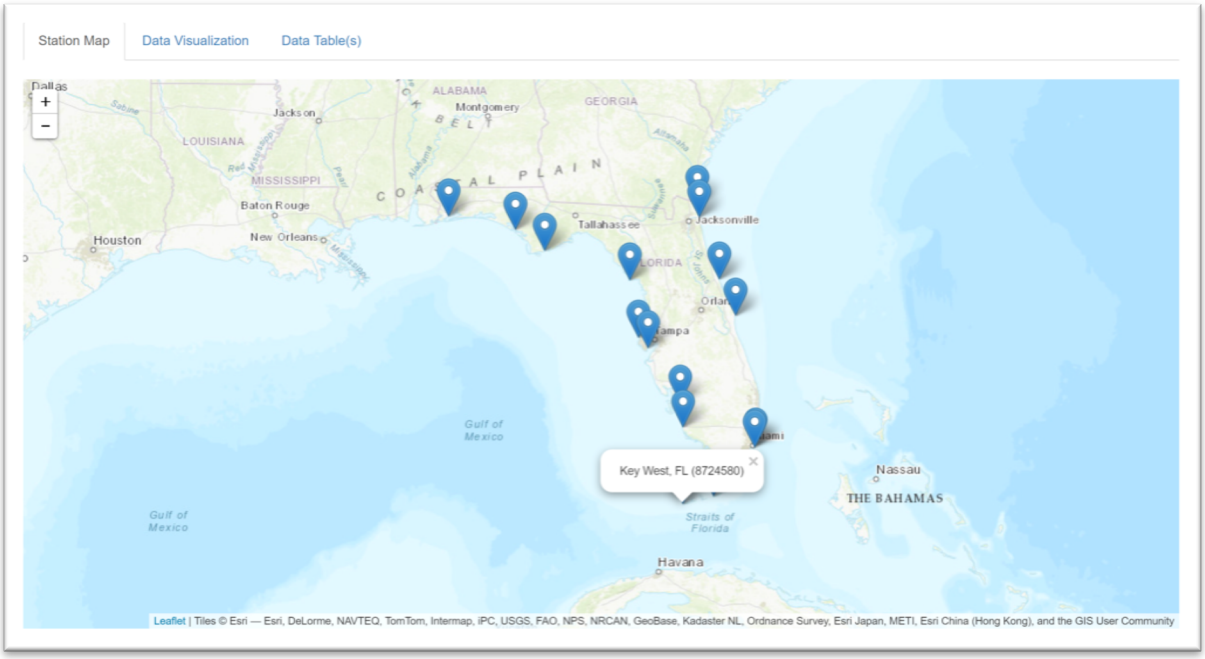


Figure 8: *Mapping pane with Key West, FL (8724580) chosen as the location and gauge for data analysis*

2.2 Visualization Panel

To the right of the data entry panel are three unique panel options. By default, when the user presses the "Visualize Selection" button, the Sea Level Tracker switches to the "Visualization" panel. When the user changes the location parameters on the data entry panel, previously generated visualizations are hidden from the UI (though they can be returned by adjusting the data entry panel's location values back to those used during the previous run of the tool). This is done to prevent any confusion between analytic outputs and configured parameters, which could be captured simultaneously by a screenshot.

While all the scenarios and values visualized are configured by within the data entry panel, the user can interact with the visualization in a number of ways.

1. ***Visualized Period of Record:*** In the top right, the user can select the period of record to visualize by entering both a start date and an end date. Alternatively, the user can click and drag to create a zoom box on the plot itself. This action will define new boundary ranges for the plot, which the Sea Level Tracker will zoom in to. If the user chooses to zoom in this way, he or she can also click the "Reset Zoom" button to return to the original plot frame. Finally, the user can also drag and adjust the window boundaries below the plot. By extending, shrinking, or adjusting these, the user will change the visualized period of record. *Note, though the user can change the window visualized in the tool, none of the scenarios adapt to these changes.*
2. ***Floating Legend:*** By hovering over the plot, a legend will appear on the user interface. This legend will enumerate the scenarios that are plotted at the date the user's cursor is hovering over, as well as the values of the scenarios at that date. The legend will appear to the top left of the user's cursor.
3. ***Capturing / Downloading the visualization:*** The user has three options for downloading or saving the configured data visualization.
    a. ***Screen capture:*** While the web browser with the Sea Level Tracker is the selected window on the user's computer, he or she can press the 'Win" and 'PrScr' buttons simultaneously to capture an image of the web browser, in its entirety. The image will

appear in the default "Screenshots" folder in the "Pictures" directory on the user's computer.

b. ***Screen capture – Snipping Tool:*** The user can also use the snipping tool to capture the visualized results. It is recommended that the user include the tooltips in this screen capture for full context.

c. ***Image Download:*** By clicking the "three bar" icon in the top right corner of the plot, the user can choose to download the visualization as either a jpeg or a png. It will appear in the user's web browser and in the user's "Downloads" directory. The metadata for the visualization will be included with the download.

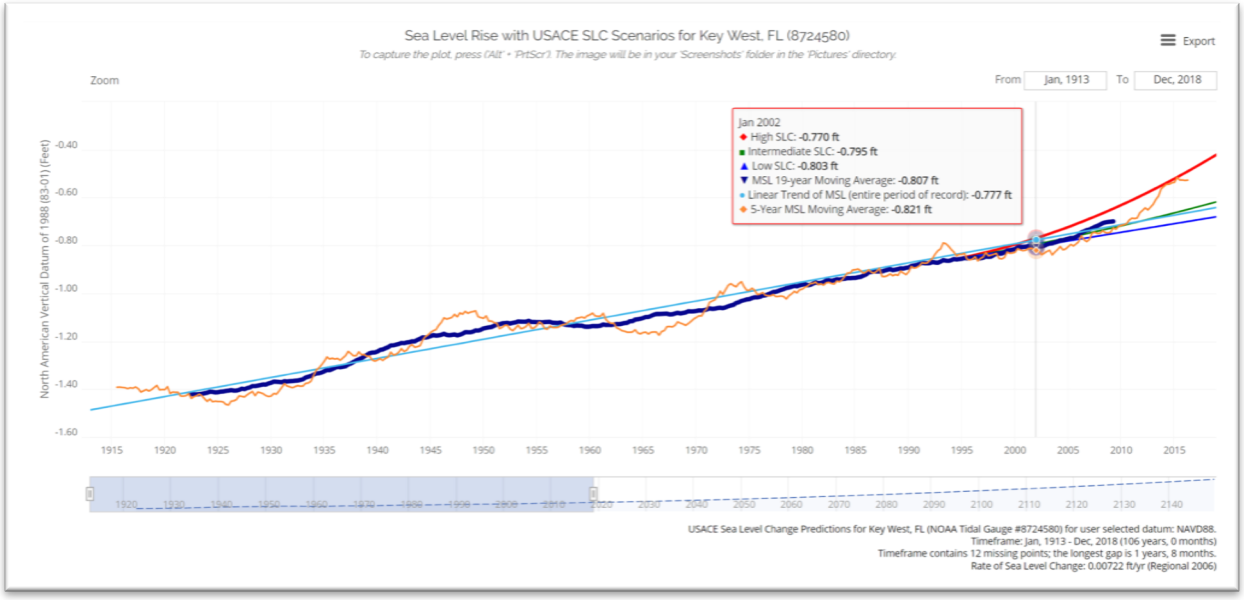


Figure 9: *The Sea Level Tracker analyzing Key West, FL (8724580), with both 19-year and 5-year MSL moving averages added to the plot, as well as a linear trend for the entire period of record*

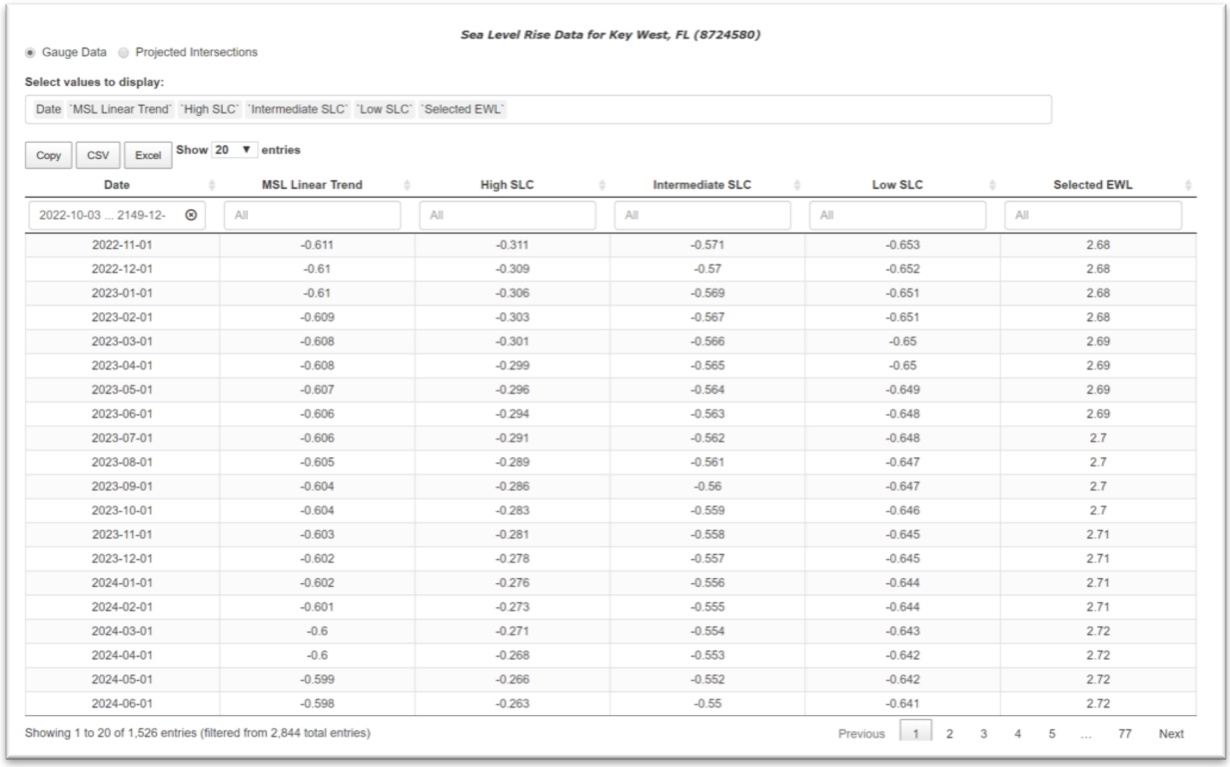
2.3 Data Table(s) Panel

To the right of the data entry panel are three unique panel options. The third and final panel option is the "Data Tables" panel. This panel has two options, 1) "Gauge Data" and 2) "Projected Intersections." The user can navigate between these options by switching between the two radio button options at the top of the panel. By default, when the user navigates to the data table(s) panel, the Sea Level Tracker presents the embedded gauge data used to visualize the analytic outputs in the data visualization panel. Alternatively, the user can view a tabular representation of the projected intersection dates for plotted critical elevations and the sea level rise scenarios. If the user chooses to view this data table but does not enter a critical elevation, no values will be present in the data table.

Primarily, the user will leverage the "gauge data" view on the data table(s) panel. Using the data entry box above the table, the user can change the variables presented in the table. By default, the table will show the raw data pulled from the NOAA API: *Date, Highest, MHHW, MHW, MSL, MLW, MLLW, and Lowest.* In this box, the user can select any of the embedded data elements in the tool by manually typing them into the box or by entering the cursor into the box and selecting the desired value from the dropdown. Values can be removed by selecting them in the bar and pressing "Backspace" or "Delete." The table will adjust with each adjustment to the table; the user is not required to press the "Visualize Selection" button again when he or she changes the table variables.

Once the desired variables are selected, the user can adjust the presented table in a number of ways. Below each variable name is a filter box. Here, the user can configure a filter or a range for a selected variable, adjusting the data in the table to fit within the desired boundaries. This feature is of particular use for the date feature, allowing the user to quickly navigate to future or historic dates of interest. Alternatively, the user can use the page buttons at the bottom right of the table to move forward or backward in time. Finally, the user can adjust the number of rows that appear on the user interface, though higher numbers will adjust the depth of the user's web browser. The Sea Level Tracker's default value is 20 entries.

For both table choices, the user can save the raw data in three different ways (presented to the user with three buttons to the top left of the table). The user can either copy the raw data to his or her computer's clipboard, or download the raw data as a ".csv" file or as an ".xslx" Excel file. When the user copies or downloaded the data, the entire dataset is extracted, not just the elements visualized in the user interface.



Sea Level Rise Data for Key West, FL (8724580)

Gauge Data Projected Intersections

Select values to display:

Date `MSL Linear Trend` `High SLC` `Intermediate SLC` `Low SLC` `Selected EWL`

Copy CSV Excel Show 20 entries

Date	MSL Linear Trend	High SLC	Intermediate SLC	Low SLC	Selected EWL
2022-10-03 ... 2149-12-	All	All	All	All	All
2022-11-01	-0.611	-0.311	-0.571	-0.653	2.68
2022-12-01	-0.61	-0.309	-0.57	-0.652	2.68
2023-01-01	-0.61	-0.306	-0.569	-0.651	2.68
2023-02-01	-0.609	-0.303	-0.567	-0.651	2.68
2023-03-01	-0.608	-0.301	-0.566	-0.65	2.69
2023-04-01	-0.608	-0.299	-0.565	-0.65	2.69
2023-05-01	-0.607	-0.296	-0.564	-0.649	2.69
2023-06-01	-0.606	-0.294	-0.563	-0.648	2.69
2023-07-01	-0.606	-0.291	-0.562	-0.648	2.7
2023-08-01	-0.605	-0.289	-0.561	-0.647	2.7
2023-09-01	-0.604	-0.286	-0.56	-0.647	2.7
2023-10-01	-0.604	-0.283	-0.559	-0.646	2.7
2023-11-01	-0.603	-0.281	-0.558	-0.645	2.71
2023-12-01	-0.602	-0.278	-0.557	-0.645	2.71
2024-01-01	-0.602	-0.276	-0.556	-0.644	2.71
2024-02-01	-0.601	-0.273	-0.555	-0.644	2.71
2024-03-01	-0.6	-0.271	-0.554	-0.643	2.72
2024-04-01	-0.6	-0.268	-0.553	-0.642	2.72
2024-05-01	-0.599	-0.266	-0.552	-0.642	2.72
2024-06-01	-0.598	-0.263	-0.55	-0.641	2.72

Showing 1 to 20 of 1,526 entries (filtered from 2,844 total entries) Previous 1 2 3 4 5 ... 77 Next

Figure 10: *The Sea Level Tracker data table for Key West, FL (8724580), comparing a MSL linear trend for the entire period of record with the future sea level change scenarios and extreme water levels, starting in October of 2022*

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